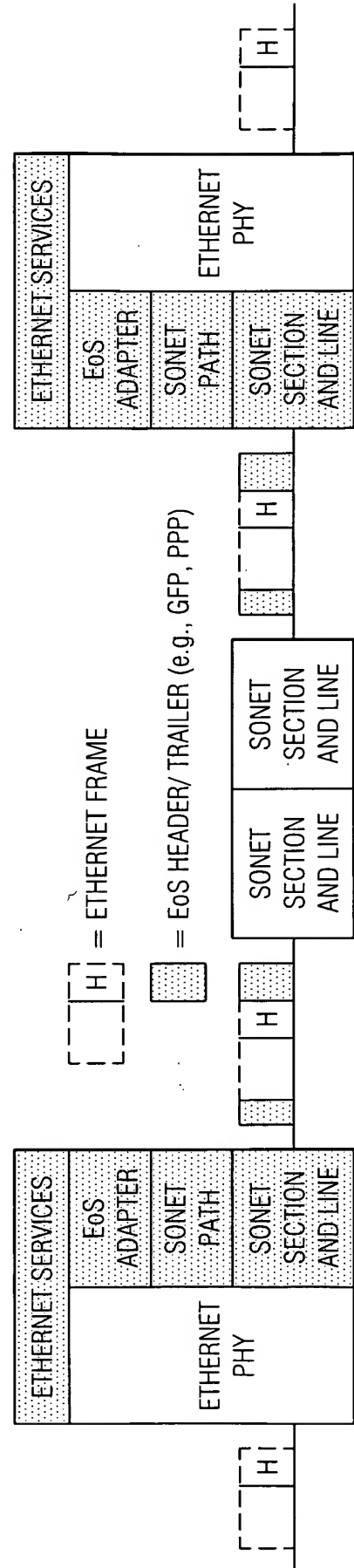**VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED
ETHERNET OVER SONET (EoS) INTERFACE AND METHOD**

Inventor: Paul F. Havala
Serial No.: 10/656,702     Filed: September 6, 2003
Attorney's Docket: 064731.0389     Sheet 1 of 16
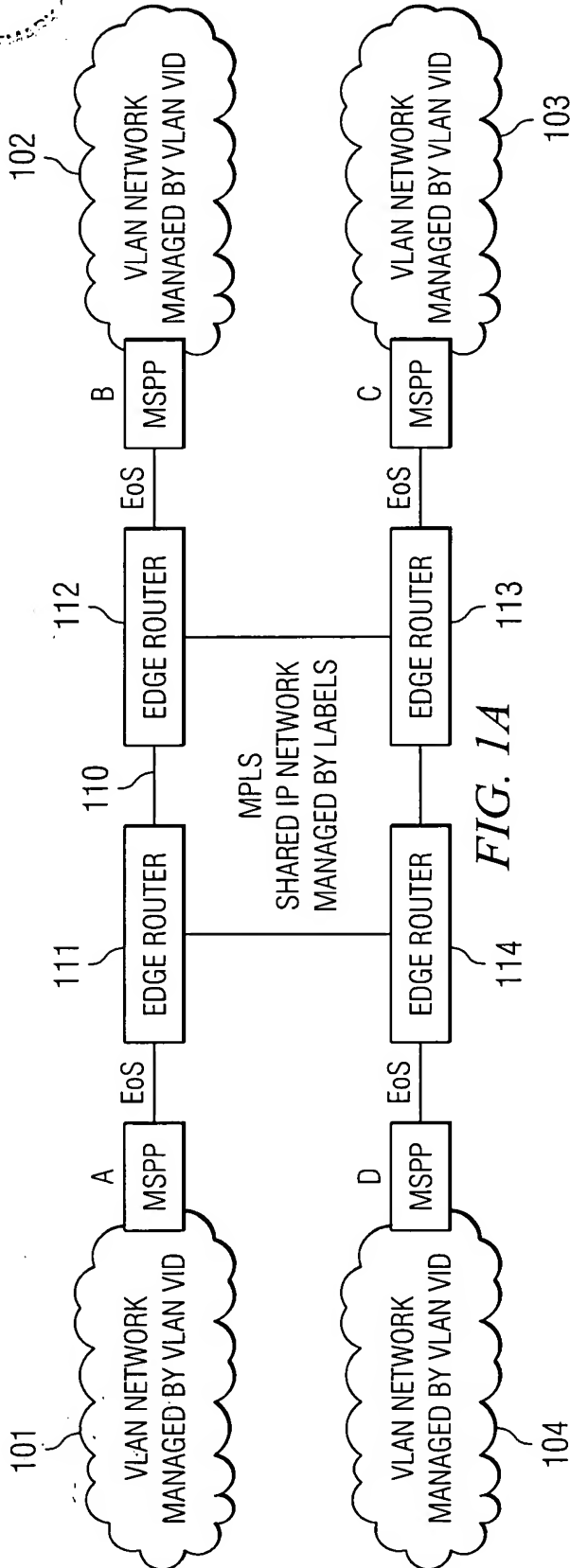
*1/16*

*FIG. 1A*



*FIG. 1B*

**VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED**
**ETHERNET OVER SONET (EoS) INTERFACE AND METHOD**
Inventor:  Paul F. Havala
Serial No.:  10/656,702   Filed:  September 6, 2003
Attorney's Docket:  064731.0389   Sheet 2 of 16
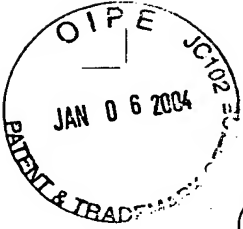
*2/16*

*FIG. 2*

VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED
ETHERNET OVER SONET (EoS) INTERFACE AND METHOD
Inventor:          Paul F. Havala
Serial No.:        10/656,702          Filed:  September 6, 2003
Attorney's Docket:  064731.0389                 Sheet 3 of 16

3/16

**FIG. 3**

VLAN PACKET 150: ...IP | TYPE | TAG | SOURCE MAC | DESTINATION MAC

MPLS PACKET 154: ...IP | VPN LABEL (156) | FORWARDING LABEL (158) | TYPE | SOURCE MAC | DESTINATION MAC

152  SWAP

**FIG. 4A** (124)

| VLAN ID (VID) | VPN LABEL |
|---|---|
| N | M |
| N+1 | M+1 |
| ... | ... |
| N' | M' |

**FIG. 4B**

| OUTGOING I/F | EoS I/F (PORT) | EoS SUB I/F (CHANNELS) |
|---|---|---|
| EoS 0 | 1 | 1-6 |
| EoS 1 | 1 | 7 |
| EoS 2 | 2 | 1 |
| ... | ... | ... |
| EoS N | | |

**VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED**
**ETHERNET OVER SONET (EoS) INTERFACE AND METHOD**
Inventor:                Paul F. Havala
Serial No.:            10/656,702              Filed: September 6, 2003
Attorney's Docket:    064731.0389                        Sheet 4 of 16

*4/16*

*FIG. 5*

**VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED
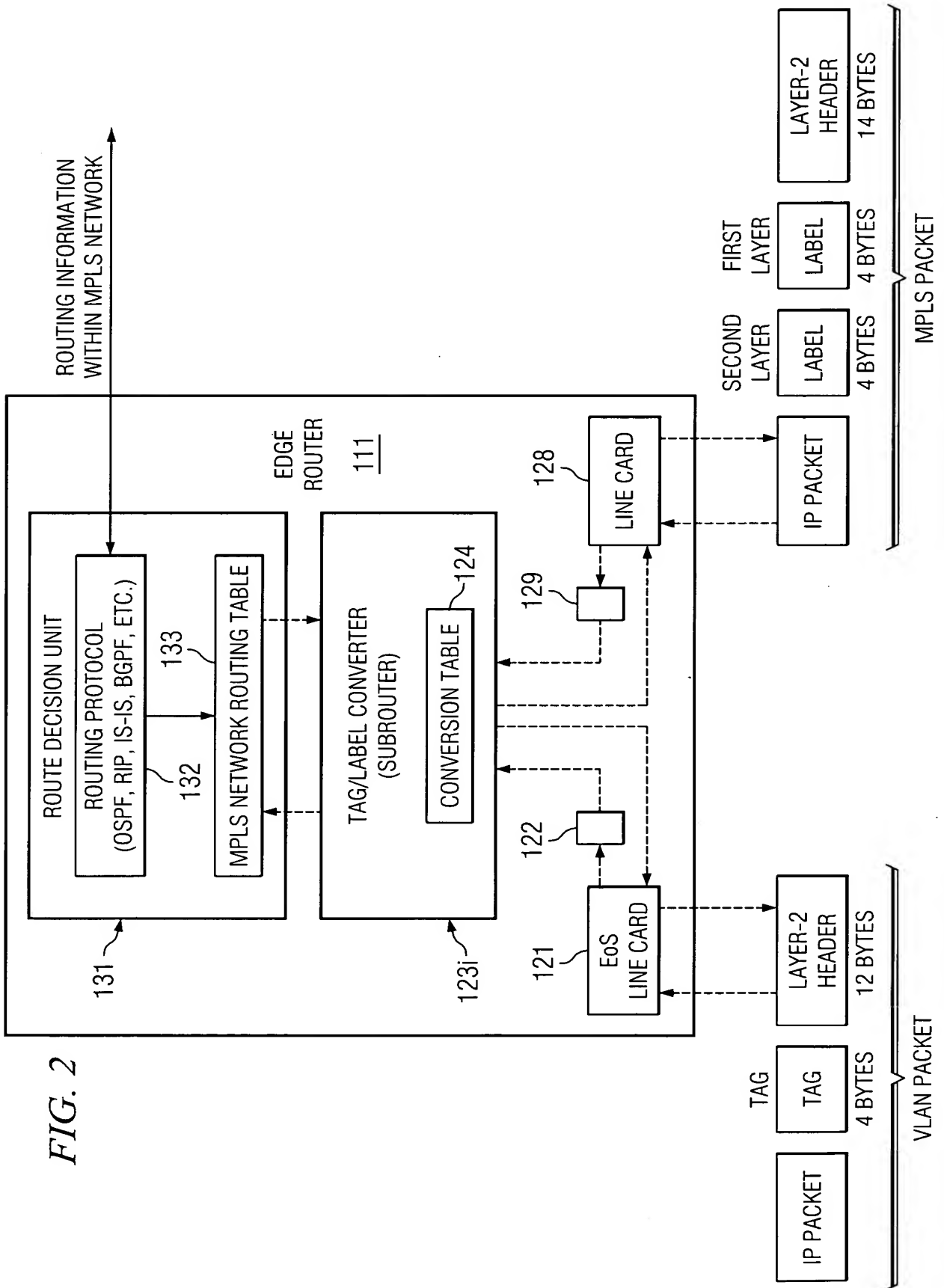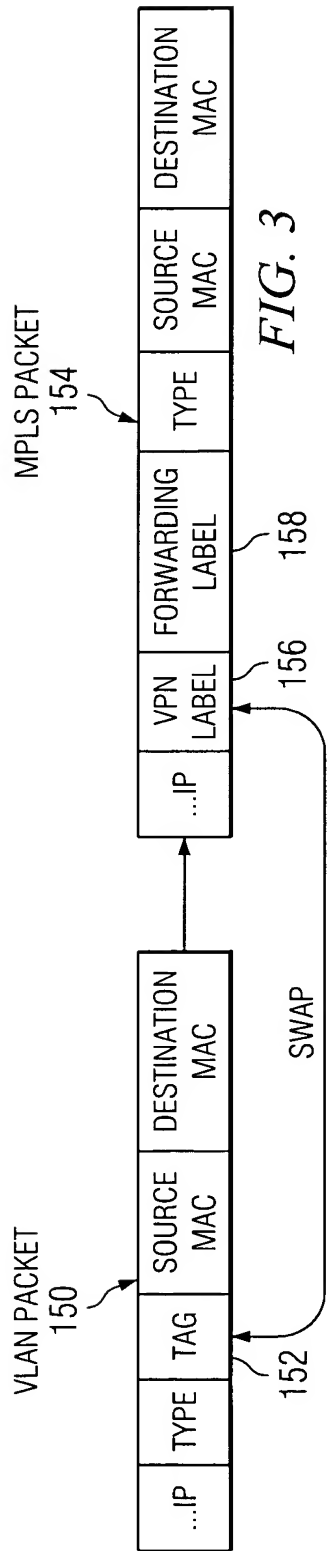ETHERNET OVER SONET (EoS) INTERFACE AND METHOD**
Inventor: Paul F. Havala
Serial No.: 10/656,702      Filed: September 6, 2003
Attorney's Docket: 064731.0389      Sheet 5 of 16

5/16

*FIG. 6*

VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED
ETHERNET OVER SONET (EoS) INTERFACE AND METHOD
Inventor:            Paul F. Havala
Serial No.:          10/656,702          Filed: September 6, 2003
Attorney's Docket:   064731.0389                 Sheet 6 of 16

6/16

ENTERPRISE A
[L2 (VLAN) OVER MPLS]

SHB — L2 SWITCHING HUB

TOKYO
ENTERPRISE A    CPE
214

OSAKA
CPE    ENTERPRISE A
231

VLAN=101

VLAN=1501

NOYAGA
CPE    ENTERPRISE A
221

VLAN=152

FIG. 7A

ENTERPRISE B
(CONNECTED TO INTERNET)

L2/3 SWITCHING HUB — SHB'

ENTERPRISE B    CPE
216

205

FW

VLAN=2

INTERNET

FIG. 7B                              204

ENTERPRISE C
(MPLS/VPNs)

RT — ROUTER

NOYAGA
ENTERPRISE C    CPE
224

OSAKA
CPE    ENTERPRISE C
234

223

FIG. 7C                              233

**VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED**
**ETHERNET OVER SONET (EoS) INTERFACE AND METHOD**
Inventor: Paul F. Havala
Serial No.: 10/656,702     Filed: September 6, 2003
Attorney's Docket: 064731.0389     Sheet 7 of 16

*7/16*

*FIG. 8*

VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED
ETHERNET OVER SONET (EoS) INTERFACE AND METHOD
Inventor:           Paul F. Havala
Serial No.:         10/656,702              Filed: September 6, 2003
Attorney's Docket:  064731.0389                    Sheet 8 of 16

8/16

FIG. 9

**VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED**
**ETHERNET OVER SONET (EoS) INTERFACE AND METHOD**
Inventor:        Paul F. Havala
Serial No.:      10/656,702        Filed: September 6, 2003
Attorney's Docket:  064731.0389              Sheet 9 of 16

*9/16*

## FIG. 10A

**(a)** L2 VPN LABEL TABLE OF PE A                    124

| PE A #VPN IDENTIFIER | | | LABEL TABLE OF ENTERPRISE A | |
|---|---|---|---|---|
| VPN LABEL | L2 ADDRESS | OUTGOING I/F | VLAN ID (VID) | VPNi |
| 26 | | | 101 | COMPANY-A |

VLAN ID AND VPN IDENTIFIER
ENTERED STATICALLY WHEN
VPN/VLAN IS SET UP

**(b)** L2 VPN ROUTING TABLE OF PE A

| PE A #VPN IDENTIFIER        ROUTING TABLE OF ENTERPRISE A |
|---|
|  |
|  |
|  |

125

## FIG. 10B

**(a)** L2 VPN LABEL TABLE OF PE A                    124

| PE A #VPN IDENTIFIER | | | LABEL TABLE OF ENTERPRISE A | |
|---|---|---|---|---|
| VPN LABEL | L2 ADDRESS | OUTGOING I/F | VLAN ID (VID) | VPNi |
| 26 | MACA | EoS      0 | 101 | COMPANY-A |

**(b)** L2 VPN ROUTING TABLE OF PE A

| PE A #VPN IDENTIFIER    ROUTING TABLE OF ENTERPRISE A |
|---|
| LOOPBACK ADDRESS OF L2 MAC B VIA PE B; VLAN 152 |
| LOOPBACK ADDRESS OF L2 MAC C VIA PE C; VLAN 1501 |
| L2 MAC A IS DIRECTLY CONNECTED, ETHERNET0, VLAN 101 |

SET UP BY iBGP {

DIRECT CONNECT BECAUSE
CPE IS DIRECTLY
CONNECTED TO OWN PE

125

VPN TABLE OF ENTERPRISE A IN PE A

| L2 VPN LABEL TABLE OF ENTERPRISE A | | | | |
|---|---|---|---|---|
| VPN LABEL | OUTGOING I/F | MAC | VID | VPNi |
| 26 | EoS | MAC A | 101 | COMPANY A |
| **L2 VPN ROUTING TABLE OF ENTERPRISE A** | | | | |
| L2    MAC B | LOOPBACK ADDRESS OF PE B; VLAN 152 | | | |
| L2    MAC C | LOOPBACK ADDRESS OF PE C; VLAN 1501 | | | |
| L2    MAC A | DIRECTLY CONNECTED, ETHERNET, VLAN 101 | | | |

*FIG. 11A*

VPN TABLE OF ENTERPRISE A IN PE B

| L2 VPN LABEL TABLE OF ENTERPRISE A | | | | |
|---|---|---|---|---|
| VPN LABEL | OUTGOING I/F | MAC | VID | VPNi |
| 26 | EoS | MAC B | 152 | COMPANY A |
| **L2 VPN TABLE OF ENTERPRISE A** | | | | |
| L2    MAC B | DIRECTLY CONNECTED, ETHERNET, VLAN 152 | | | |
| L2    MAC C | LOOPBACK ADDRESS OF PE C; VLAN 1501 | | | |
| L2    MAC A | LOOPBACK ADDRESS OF PE A; VLAN 101 | | | |

*FIG. 11B*

VPN TABLE OF ENTERPRISE A IN PE C

| L2 VPN LABEL TABLE OF ENTERPRISE A | | | | |
|---|---|---|---|---|
| VPN LABEL | OUTGOING I/F | MAC | VID | VPNi |
| 26 | EoS | MAC C | 1501 | COMPANY A |
| **L2 VPN LABEL TABLE OF ENTERPRISE A** | | | | |
| L2    MAC B | LOOPBACK ADDRESS OF PE B; VLAN 152 | | | |
| L2    MAC C | DIRECTLY CONNECTED, ETHERNET, VLAN 1501 | | | |
| L2    MAC A | LOOPBACK ADDRESS OF PE A; VLAN 101 | | | |

*FIG. 11C*

VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED
ETHERNET OVER SONET (EoS) INTERFACE AND METHOD
Inventor:          Paul F. Havala
Serial No.:        10/656,702          Filed: September 6, 2003
Attorney's Docket: 064731.0389                 Sheet 11 of 16

11/16

FIG. 12

*12/16*

ENTER PACKET

301

TAGGED? — NO

YES

302 — REFER TO VLAN ID

303

LESS THAN 4096 ? — NO

YES

304 — REFER TO VLAN ID AND VPN LABEL CONVERSION TABLE

DISCARD

305

LABEL VALUE FOUND ? — NO

YES

306 — REMOVE TAG AND IMPOSE L2 LABEL VALUE (BY REFERRING TO VPN LABEL TABLE)

307 — SEARCH L2 VPN ROUTING TABLE BASED UPON DESTINATION MAC ADDRESS OF PACKET, AND ACQUIRE LOOPBACK ADDRESS OF TRANSMIT-SIDE EDGE ROUTER

308 — ACQUIRE PUSH LABEL FROM FORWARDING LABEL TABLE BASED UPON LOOPBACK ADDRESS

309 — IMPOSE THIS LABEL VALUE ON LAYER 1 AND SEND PACKET THROUGH MPLS NETWORK

GO TO ORDINARY MPLS PROCESSING

A

TO FIG. 14

*FIG. 13*

VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED
ETHERNET OVER SONET (EoS) INTERFACE AND METHOD
Inventor:          Paul F. Havala
Serial No.:        10/656,702          Filed: September 6, 2003
Attorney's Docket: 064731.0389                Sheet 13 of 16

*13/16*

FROM
FIG. 13

A

310 — EXECUTE PROCESSING TO ROUTE
LABEL THROUGH MPLS NETWORK

311 — HAS MPLS PACKET ARRIVED AT PE ROUTER? — NO

YES

312 — REMOVE LABEL VALUE BELONGING TO LAYER 1

313 — REFER TO LAYER-2 LABEL VALUE

314 — REFER TO VLAN ID AND VPN LABEL CONVERSION TABLE

LABEL VALUE FOUND ? — NO

315 YES

316 — REMOVE LAYER-2 LABEL VALUE AND ADD TAG

317 — REFER TO VPN LABEL TABLE AND OUTPUT PACKET TO SUITABLE INTERFACE

318 — EXECUTE ORDINARY VLAN PROCESSING

DISCARD

END

*FIG. 14*

**VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED**
**ETHERNET OVER SONET (EoS) INTERFACE AND METHOD**

Inventor:       Paul F. Havala

Serial No.:       10/656,702       Filed: September 6, 2003

Attorney's Docket:       064731.0389       Sheet 14 of 16

*14/16*

*FIG. 15A*

VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED
ETHERNET OVER SONET (EoS) INTERFACE AND METHOD
Inventor: Paul F. Havala
Serial No.: 10/656,702        Filed: September 6, 2003
Attorney's Docket: 064731.0389        Sheet 15 of 16

*15/16*

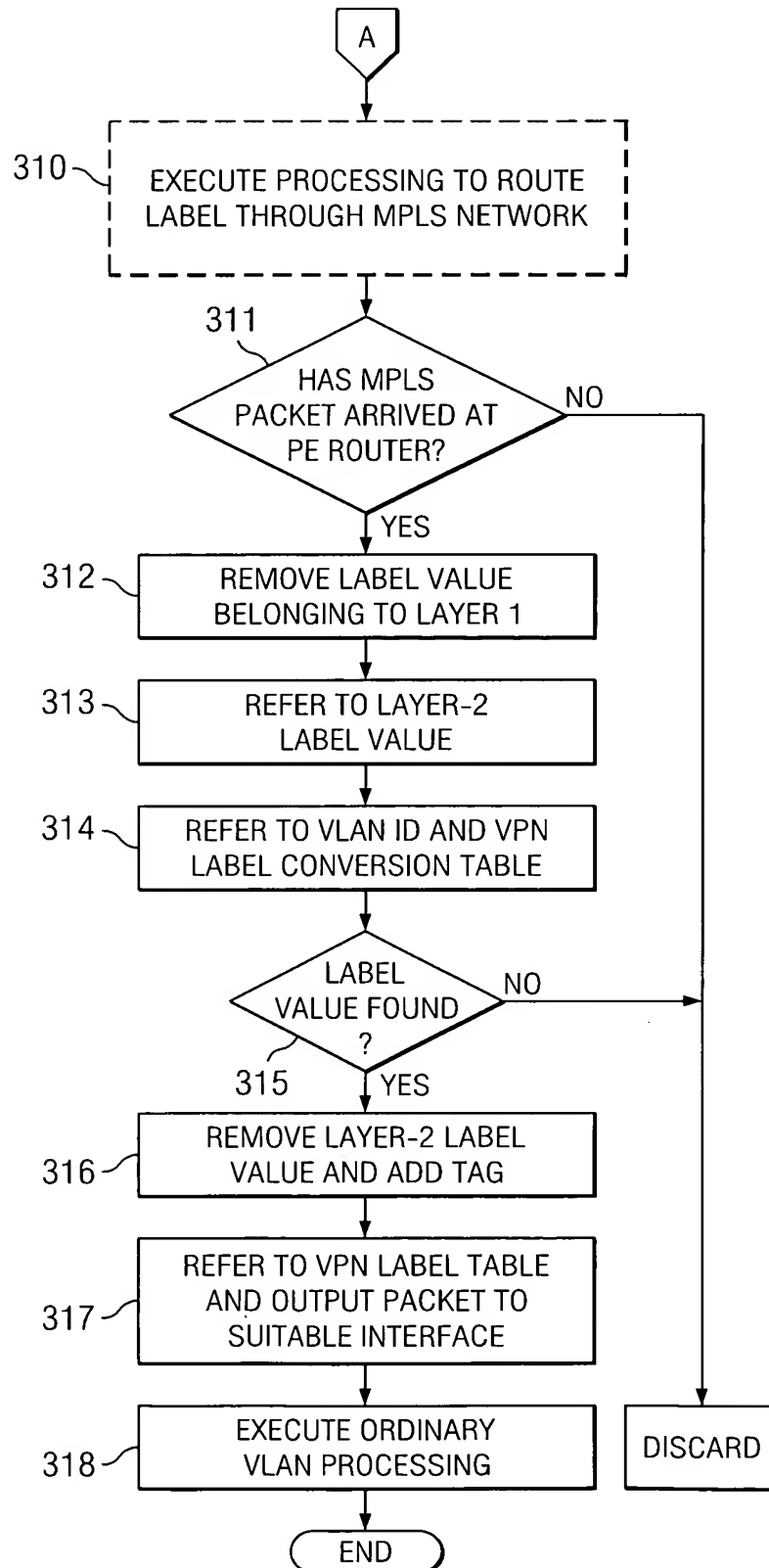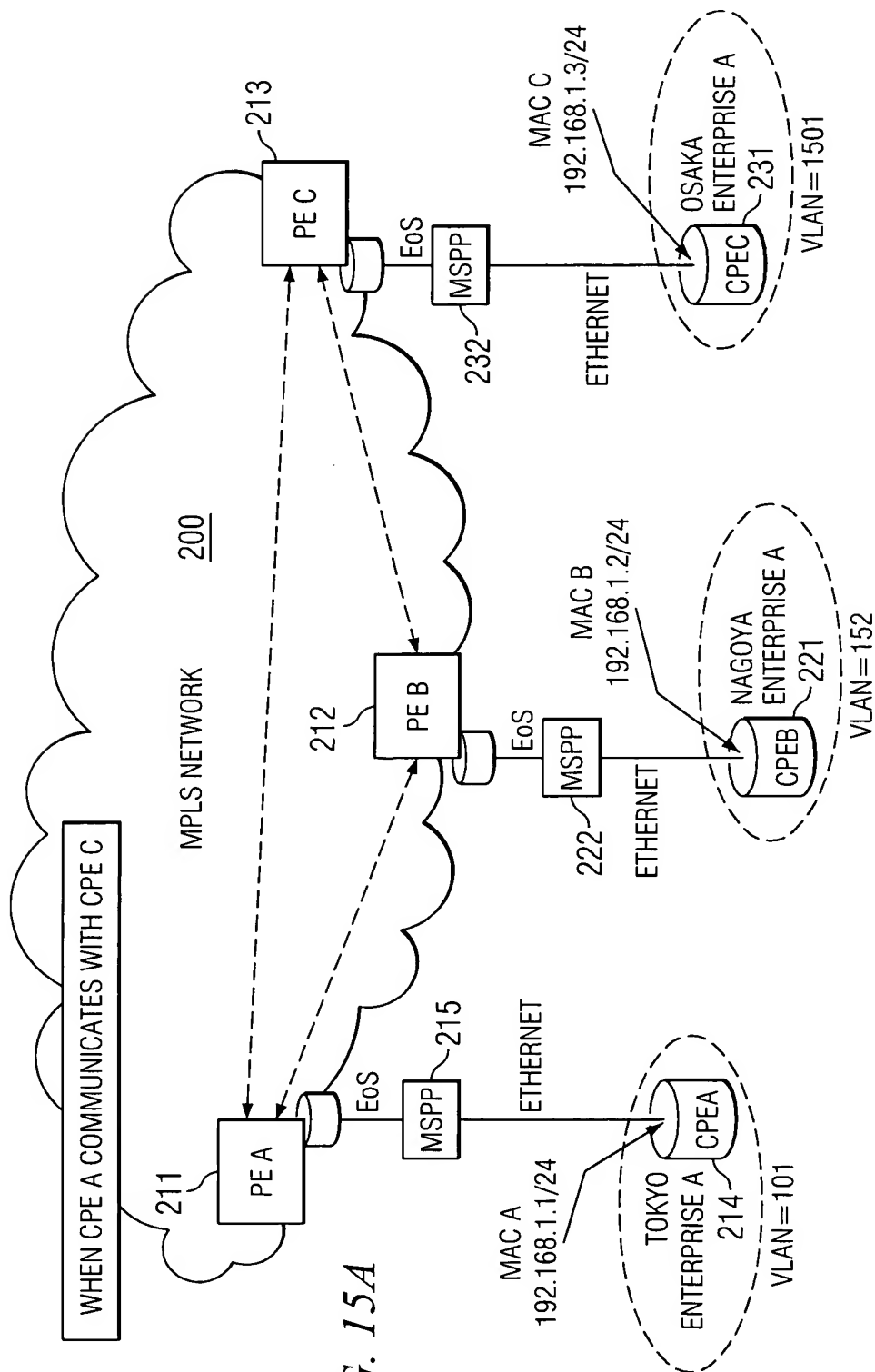| | |
|---|---|
| 1. | BROADCAST ARP PACKET DIRECTED TO CPE C (192.168.1.3) FROM CPE A |
| 2. | IN CASE OF BROADCAST DIRECTED TO CPE C (192.168.1.3) FROM CPE A, CREATE COPY OF BROADCAST PACKET AT PE A AS NECESSARY AND SEND PACKET TO PE B, PE C |
| 3. | SEND ARP-REPLY PACKET TO CPE A (192.168.1.1) FROM CPE C AUTOMATICALLY LEARN OR ENTER MAC ADDRESS OF EACH CPE IN L2 VPN LABEL TABLE, L2 VPN TABLE OF EACH PE |

*FIG. 15B*

START

401 — SET VLAN ID (VID), VPN IDENTIFIER IN EACH PE ROUTER WITH REGARD TO PRESCRIBED VPN

402 — SET PAIR OF COMMUNICATION-DISABLED VLANs

403 — CREATE VPN LABEL TABLE AUTOMATICALLY BY EACH PE

404 — AUTOMATICALLY CREATE DIRECT-CONNECT INFORMATION OF L2 VPN TABLE BY EACH PE

405 — TRANSMIT VPN ROUTING INFORMATION TO PE ROUTERS UNDER CONTROL OF VLANs NOT FORBIDDEN TO COMMUNICATE (DO NOT TRANSMIT VPN ROUTING INFLORMATION TO PE ROUTERS UNDER CONTROL OF COMMUNICATION-DISABLED VLANs)

406 — RECEIVE VPN ROUTING INFORMATION FROM OTHER PE ROUTERS AND COMPLETE L2 VPN TABLE

END

*FIG. 16*

**VIRTUAL PRIVATE NETWORK (VPN) WITH CHANNELIZED
ETHERNET OVER SONET (EoS) INTERFACE AND METHOD**
Inventor:      Paul F. Havala
Serial No.:     10/656,702     Filed: September 6, 2003
Attorney's Docket:  064731.0389     Sheet 16 of 16

*16/16*

## FIG. 17A

150

152

| 6 BYTES MAC DA | 6 BYTES MAC SA | 4 BYTES TAG | 2 BYTES TYPE | IP, TCP, DATA,... |
|---|---|---|---|---|

USER_PRIORITY

| TYPE VALUE OF TAG PROTOCOL (8100 AT TAGGING TIME) | 3 BITS | | VLAN IDENTIFIER (VID) | LENGTH | RIF |
|---|---|---|---|---|---|

## FIG. 17B

| LABEL | EXP (3 BITS) | S | TTL |
|---|---|---|---|

| 6 BYTES MAC DA | 6 BYTES MAC SA | 2 BYTES TYPE | 4 BYTES LABEL | IP, TCP, DATA,... |
|---|---|---|---|---|

154